

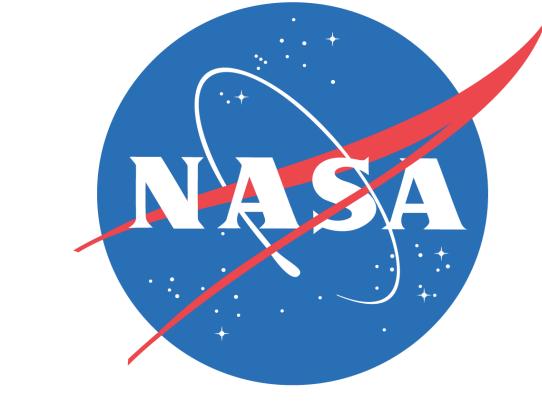
# ECCO2: High Resolution Global Ocean and Sea Ice Data Synthesis

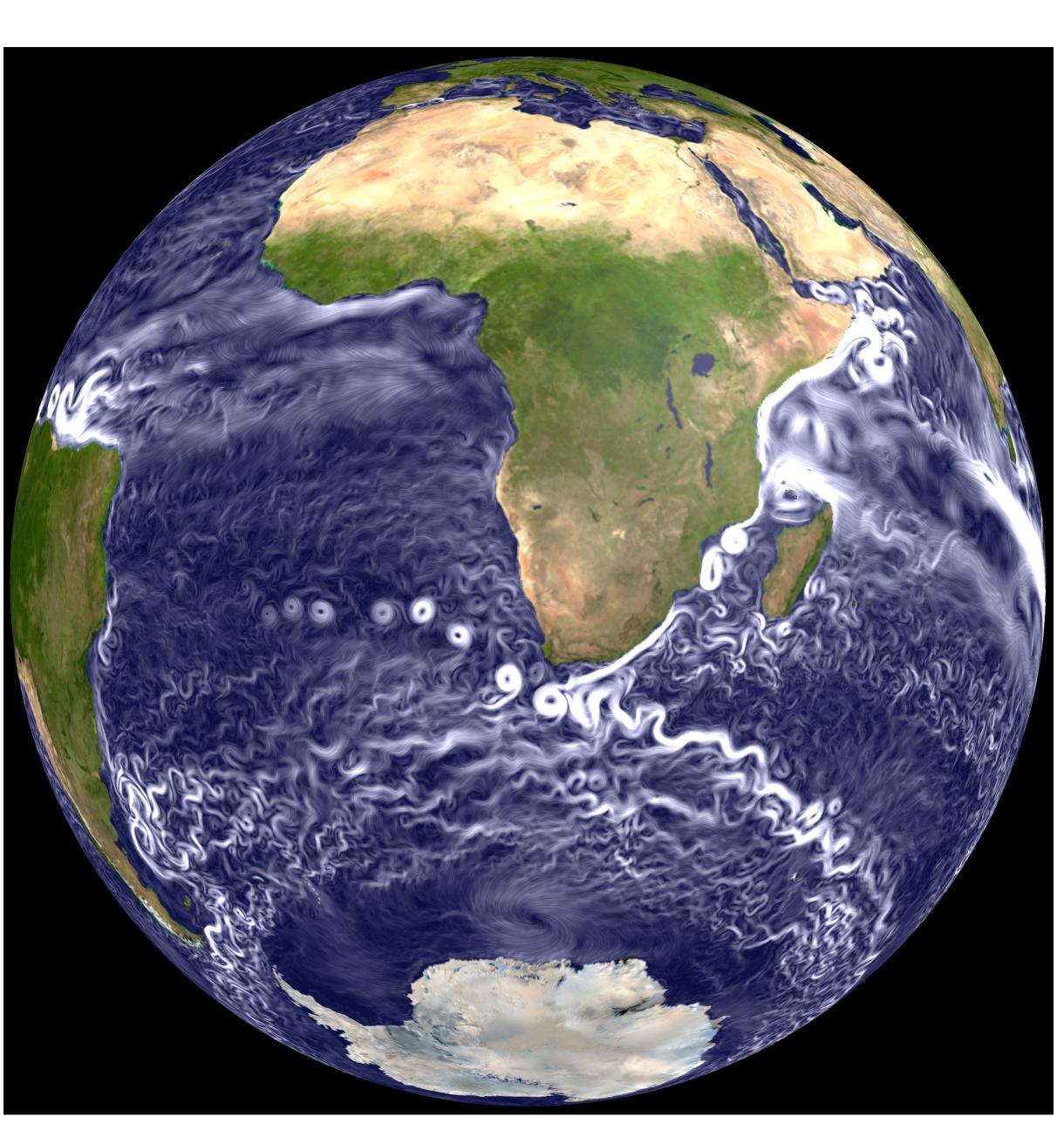
http://ecco2.org

Drake Passage Transport (Schodlok)

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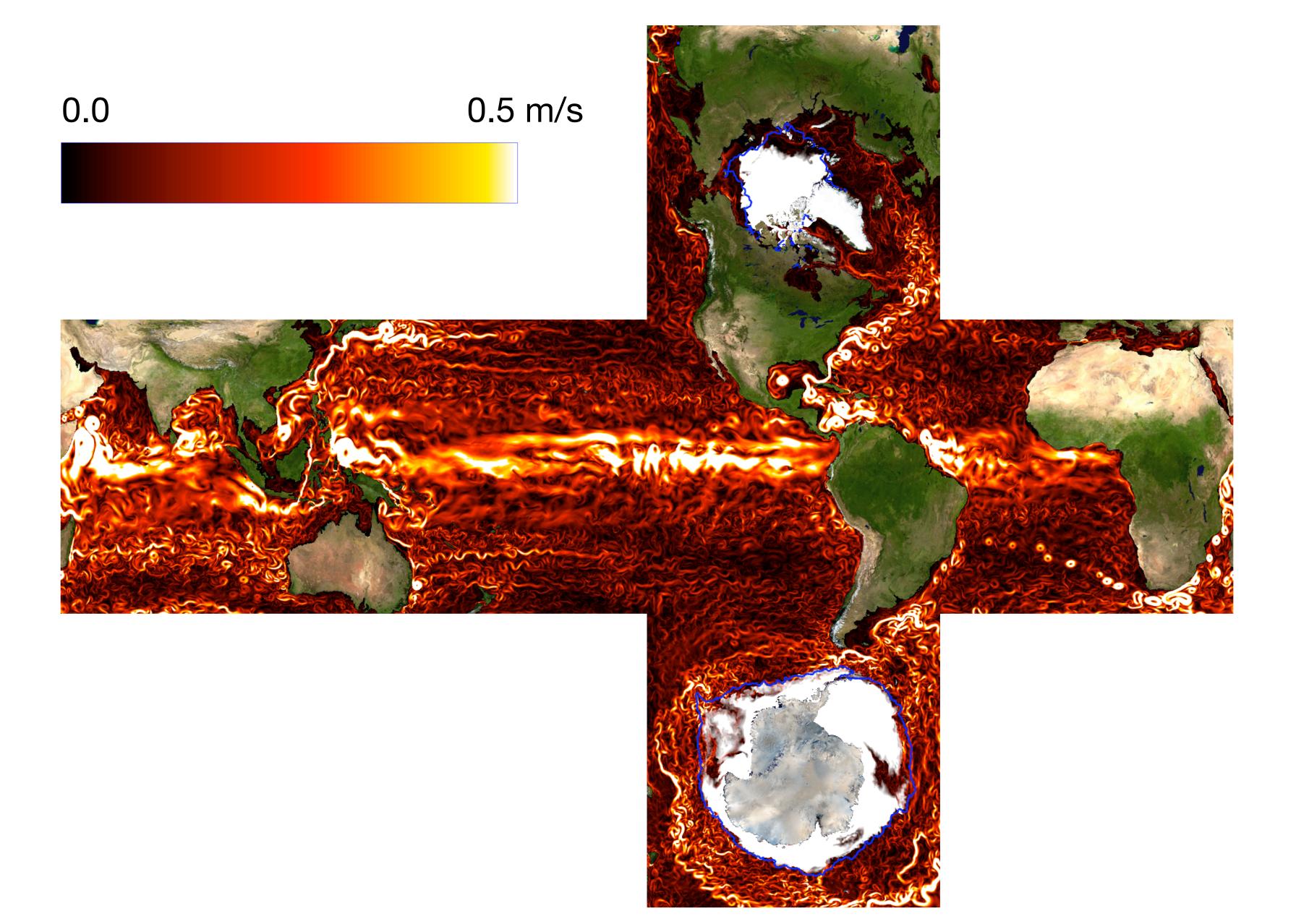
http://map.nasa.gov





#### Ocean State Estimation in the presence of eddies and ice

The Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2, http://ecco2.org) project aims to produce a best-possible, time-evolving synthesis of most available ocean and sea-ice data at a resolution that admits ocean eddies. ECCO2 analyses are obtained via least squares fit of a global, full-depth-ocean, and sea-ice configuration of the Massachusetts Institute of Technology general circulation model (MITgcm, http://mitgcm.org) to the available satellite and in-situ data. What sets apart ECCO2 analyses from operational high-resolution ocean data assimilation products is their physical consistency; in particular, the analyses do not contain discontinuities when and where data are ingested. ECCO2 data syntheses are being used to quantify the role of the oceans in the global carbon cycle, to understand the recent evolution of the polar oceans, to monitor time-evolving term balances within and between different components of the Earth system, and for many other science applications.

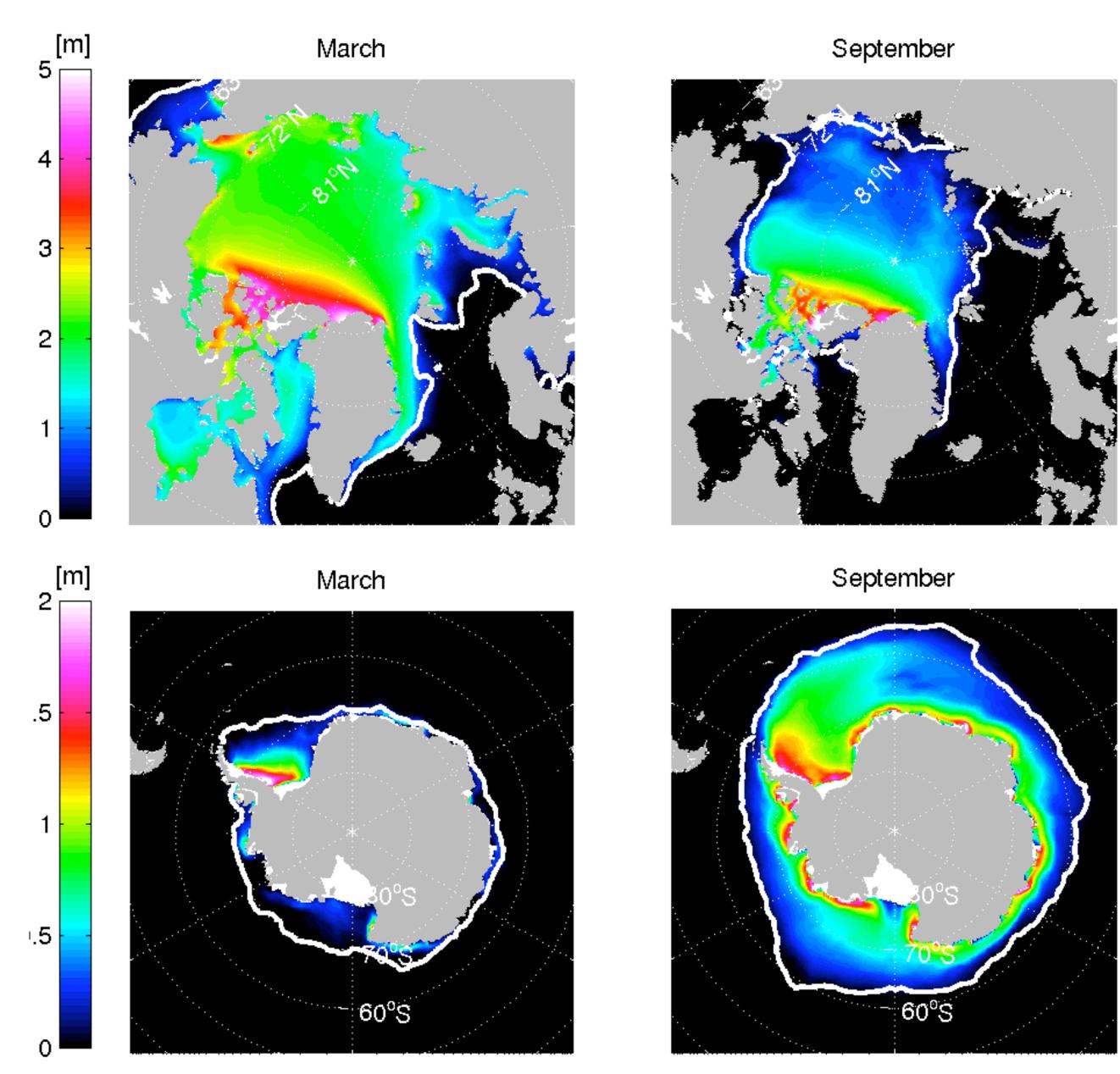


#### Global ocean and sea ice model

The computational demands of rigorous ocean state estimation are enormous. Therefore, a necessary condition is an efficient global ocean and sea ice model and significant computational resources. A first, global ECCO2 solution was obtained on a cubed-sphere coupled ocean and sea-ice configuration of the MITgcm with mean horizontal grid spacing of 18 km and 50 vertical levels.

The figure to the left shows a snapshot of simulated near-surface (15-m) ocean current speed and sea ice cover from an unconstrained eddying integration. Simulated sea-ice is shown as an opaque, white cover.

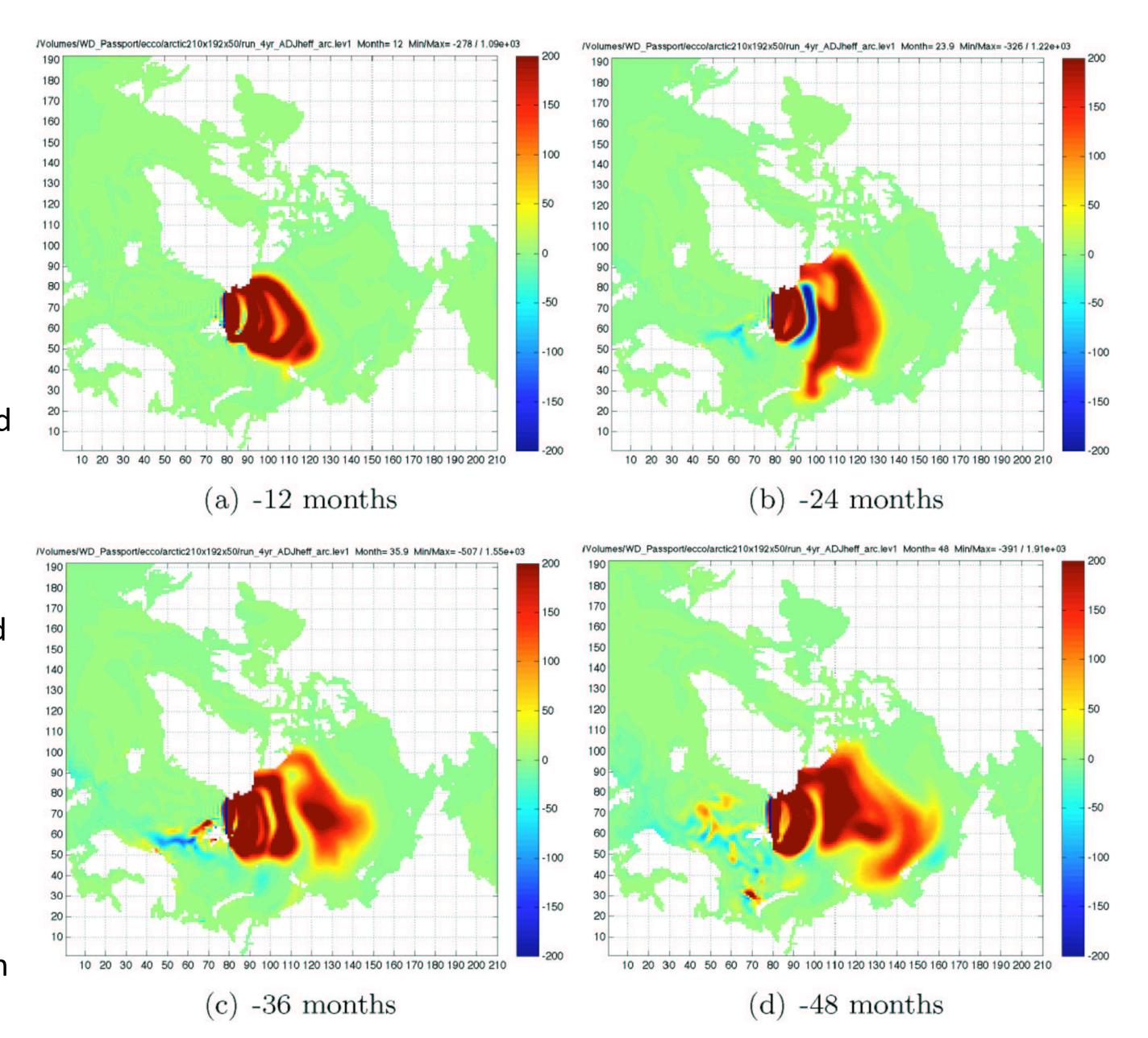
The figure to the right shows effective sea ice thickness distribution (color) averaged over the years 1992-2002. The ice edge, estimated as the 15% isoline of ice concentration retrieved from passive microwave satellite data, is drawn as a white contour line for comparison. Differences between observed and simulated sea ice extent is one of the signals, which is used to calibrate the ECCO2 solution.



### A first ECCO2 optimization

A first ECCO2 synthesis for the 1992-2002 period has been obtained using a Green's Function approach to estimate initial temperature and salinity conditions, surface boundary conditions, and several empirical model parameters. Data constraints include altimetry, gravity, drifter, hydrographic, and sea-ice data.

The figure to the left displays some of the large-scale biases that were present in the baseline integration and the equivalent fields from the optimized solution, demonstrating significant improvements of the optimized Winter ice extent compared to passive microwave data solution relative to the baseline integration. Top left panel: comparison of the 1992-2002, 0-750-m time-mean temperature of the ECCO2 baseline and optimized solutions to the World Ocean Atlas 2005 (WOA05) climatology. Top right panel: baseline (top) and optimized (bottom) Antarctic sea ice distribution on September 1992 (left) and September 2002 (right). Simulated and optimized sea extent is shown in blue. The thin white line is passive radiometer observations of sea-ice extent (15% concentration). Bottom left panel: Weddell Sea T/S properties of WGCH climatology (top), baseline integration (middle), and optimized solution (bottom). Bottom right panel: Drake Passage transport in the baseline and optimized solution is compared to the estimate of Sloyan and Rintoul (2001).

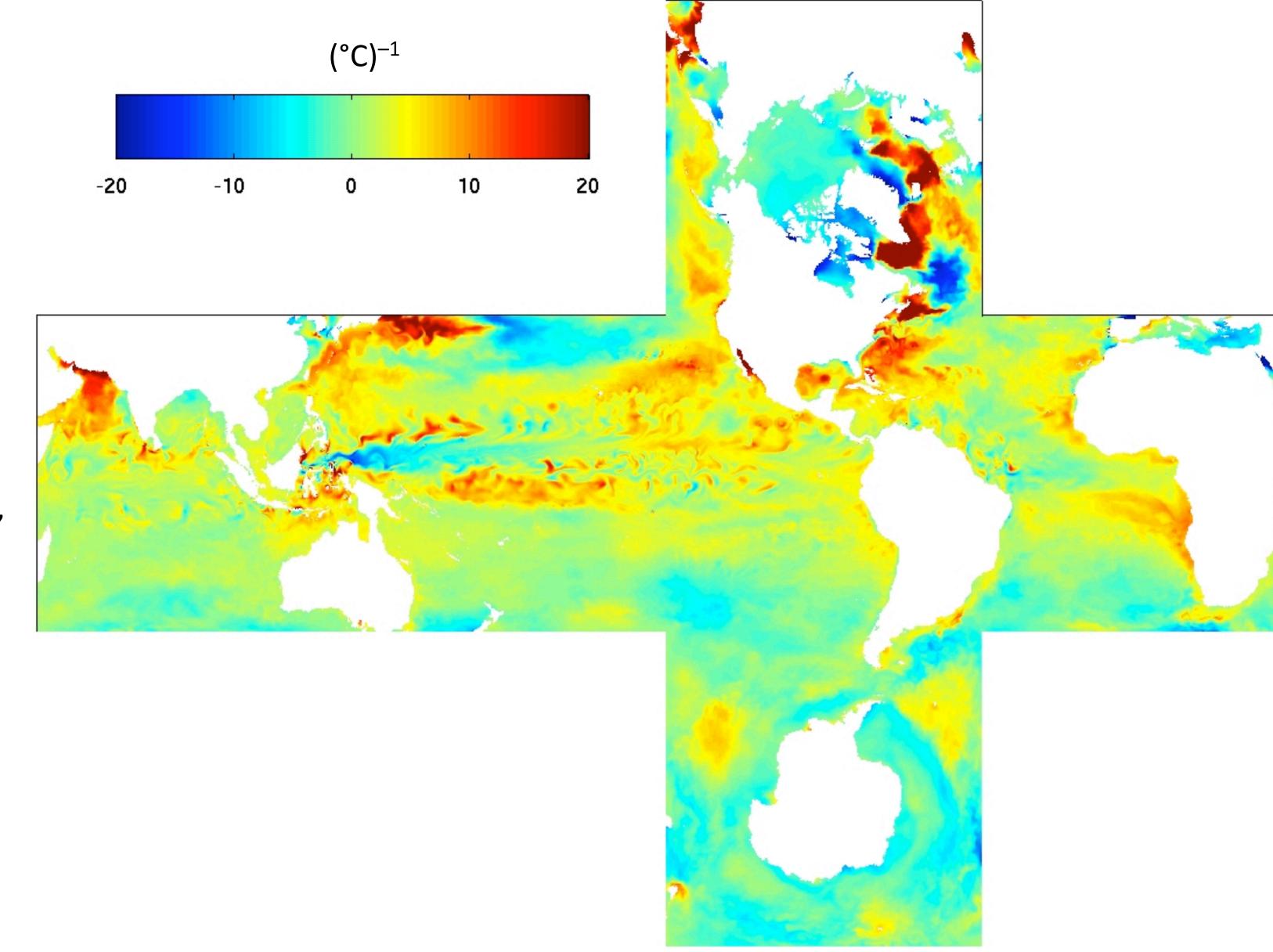


#### Adjoint ocean and sea ice modeling

In parallel with the Green's function optimization, work is underway towards adjoint-method optimization on the same grid. One objective of the MITgcm ocean and sea-ice model development effort has been to provide the capability for automatic generation of the adjoint model from up-to-date versions of the MITgcm. The coupled ocean/sea-ice adjoint now yields stable and physically meaningful adjoint sensitivities or Lagrange multipliers.

By way of example, the figure to the left depicts sensitivity maps of sea-ice export through Fram Strait during December 1995 to changes in ice thickness at any point in the domain 1, 2, 3, and 4 years prior.

The figure to the right shows adjoint sensitivity of cost function (monthly model/data quadratic misfit) to the initial temperature field at the 15-m depth. The sensitivity is shown after a 1-year adjoint integration. Red patches are regions where the model-data misfit increases and blue patches are regions where the model/data misfit decreases with increasing initial temperature. The adjoint sensitivities are a critical step towards fully constraining this global ocean and sea-ice model with NASA satellite data.



## **Available ECCO2 products**

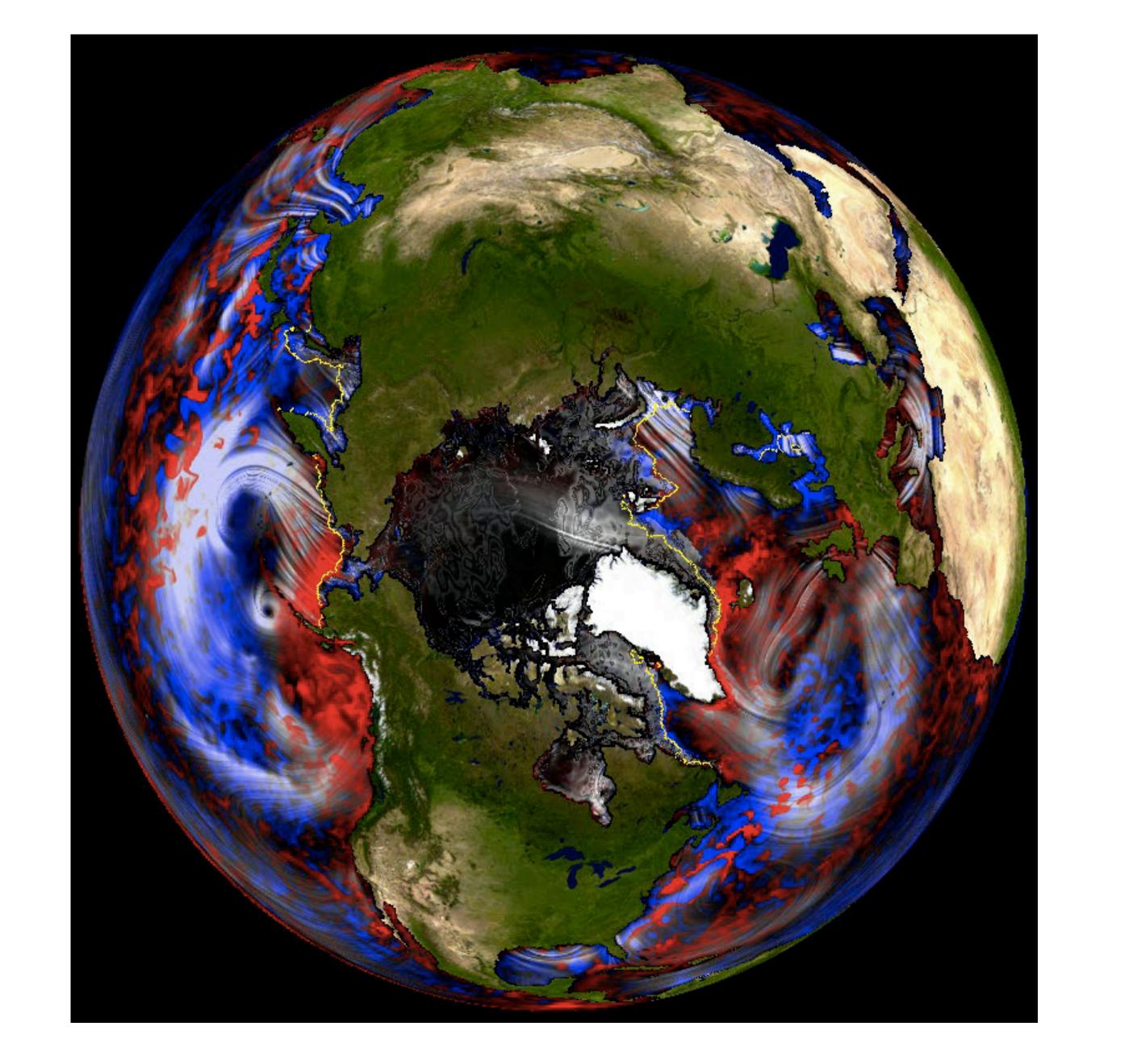
Mean 0-700 m temperature difference from climatology

Weddell Sea T/S diagram (Schodlok)

ECCO2 modeling and estimation tools and results are freely available to the scientific community. Model configurations and parameterizations are available at http://mitgcm.org. Automatic differentiation tools are available at

http://www-unix.mcs.anl.gov/OpenAD. Finally, modeling and estimation results are available at <a href="http://ecco2.org">http://ecco2.org</a>.

The ECCO2 results include quasi-global simulations at 1/4, 1/8, and 1/16-degree horizontal grid spacing, a 2005–2006 adjoint-method Southern Ocean State Estimate at 1/6-degree horizontal grid spacing, and a 1992-present global-ocean and sea-ice Green's function optimization on a cubed-sphere grid with 18 km horizontal grid spacing. For the global cubed-sphere grid configuration, in addition to the optimized solution, upwards of 80 forward model sensitivity experiments are available. There is also a longer, 1979-present, forward integration carried out using the optimized model parameters. For all of these solutions a large complement of high-frequency and high-resolution model diagnostics has been saved and is available online via ftp, http, and OPeNDAP servers.

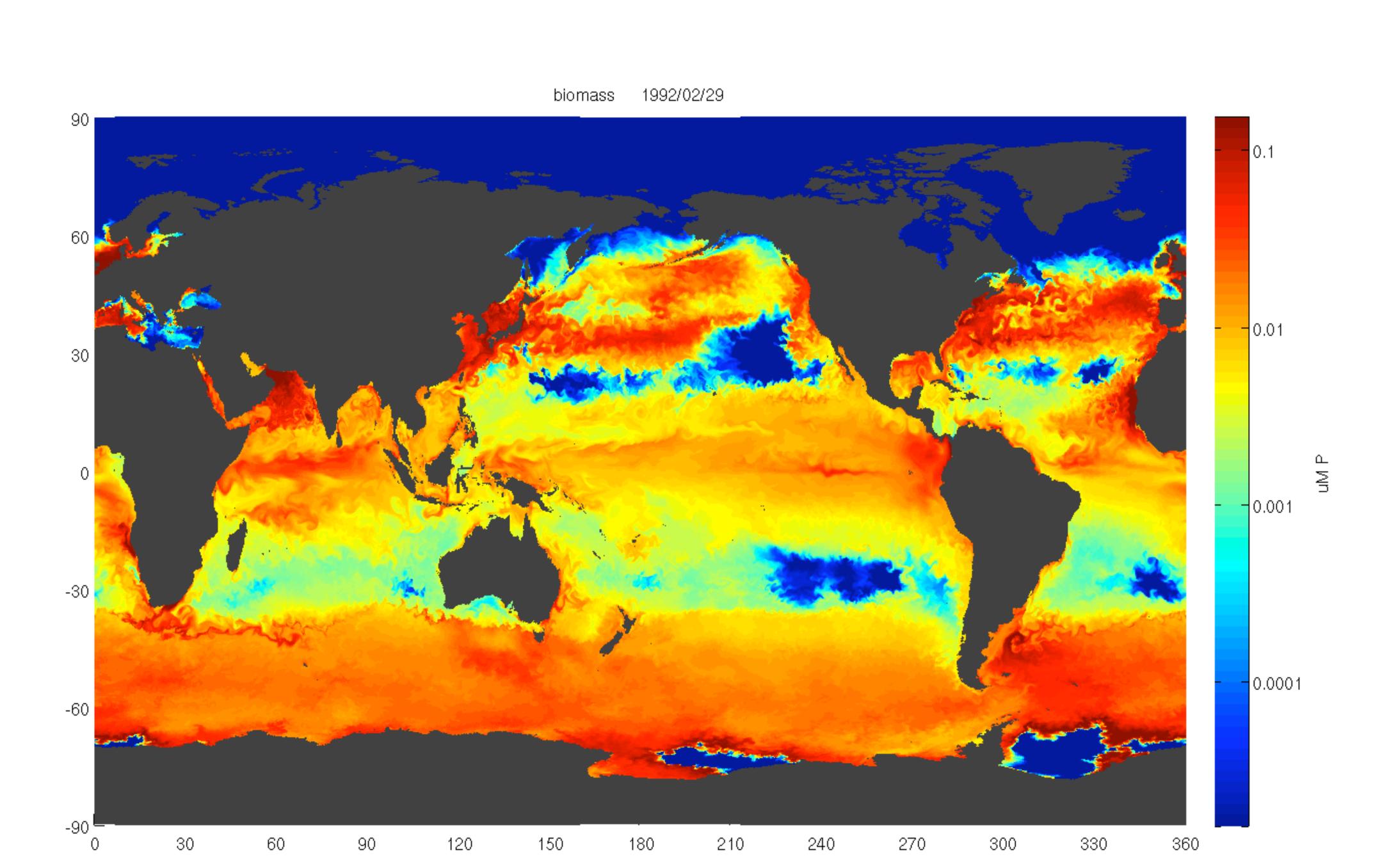


#### Early science applications

A first set of early ECCO2 science applications concerns improved error estimates and eddy parameterizations for coarse-resolution ocean simulations and estimations. A second set of early science applications concerns the impact of mesoscale eddies on large-scale ocean circulation and its variability. A third set of early science applications concerns the study of Polar Oceans. ECCO2 results are also being used to supply boundary conditions for regional studies and to drive biogeochemical, geodetic, acoustic, and electromagnetic models.

For example, the figure to the right shows results from O. Jahn and M. Follows, who used an ECCO2 solution to drive a self-assembling marine ecosystem.

Other examples of early ECCO2 science applications can be seen in posters OS31C-1291, OS31C-1293, OS31C-1294, OS31C-1295, OS31C-1298, and OS31C-1299.



#### Acknowledgments

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